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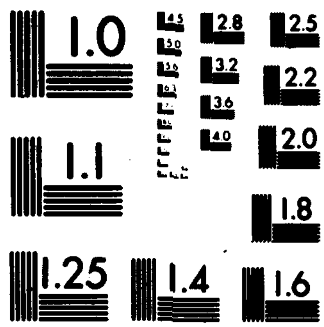

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes research results in monolithic signal processing circuits. New approaches to monolithic crystal oscillator design are described together with new circuits for temperature-stable monolithic voltage-controlled oscillators. A major new theory of noise in switching oscillators has been developed and applied. In device research, a new ion-implanted buried reference diode has been devised. A publication list describing this work is included together with a list of associated Ph.D. and M.S. reports.

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The research supported under Grant ARO DAAG29-77-G-0132 led to significant results in a number of related areas. These include new approaches to monolithic crystal oscillator design, a new theory of noise in switching oscillators and new circuits for temperature-stable high-frequency voltage-controlled oscillators. In addition, a unique ion-implanted buried reference diode was devised and tested and new methods of linear signal processing in NMOS technology were investigated.

Crystal oscillators are widely used to generate precision clock-pulse waveforms for complex integrated circuits. However, the use of on-chip crystal oscillators (with external crystals) in MOS integrated circuits has been delayed by the lack of an adequate theory of operation of these circuits. A primary problem has been lack of methods of analysis of the complex limiting nonlinearities involved. Using both theoretical analyses and computer evaluation, we defined precisely the operation of MOS crystal oscillators and devised design procedures which accurately predict the bhavior and characteristics of these circuits. Parameters such as steady-state amplitude, signal distortion, crystal power and start-up conditions can now be easily predicted. This work is described in publication three of the attached list.

Voltage-controlled oscillators (VCOs) are widely used in modern communication and control systems and other signal processing systems. Monolithic versions of such circuits have been the driving force behind this widespread useage, but previously-available circuits had severe limitations at operating frequencies above 200 kHz. Our work in this area has resulted in the realization of a high-frequency monolithic voltage controlled oscillator with temperature stability one hundred times better than existing circuits. The circuit was fabricated in our IC facility using an advanced monolithic bipolar process (f_T = 4 GHz)

and achieved better than 60 ppm/°C frequency drift with temperature at center frequencies from dc to 20 MHz. The circuit is based on very fast current switching into a grounded capacitor. The current switches are controlled by a unique temperature-compensated trigger circuit which simultaneously achieves nanosecond switching and highly stabilized trigger points. The unique circuit topology realizes a factor of 25 improvement in performance over existing circuits. The high-frequency process yields another factor of 4 giving temperature stability in the VCO at 20 MHz which was previously unattainable beyond 200 KHz.

Our research in VCOs revealed the importance of phase noise as a major limitation on the performance of these circuits. Extensive literature surveys revealed a total lack of published theories to describe this phenomenon and allow optimization of circuit performance. Our research in this area has generated a new thoery of noise in relaxation oscillators with important implications in a wide variety of applications. The new theory, which is quite general in nature, allows for the first time the exact prediction of noise in relaxation oscillators and has shown all circuits and device parameters contributing to noise performance. Initial applications of the theory resulted in a measured factor of 100 reduction of phase noise (Jitter) in a practical voltage-controlled oscillator. The theory is based on formulation of the switching cycle of a relaxation oscillator by a nonlinear differential equation of quite general form. Use of a random excitation signal predicts noise performance whereas a repetitive input waveform allows prediction of synchronization behavior. The theory is quite independent of existing theories of noise in high-Q L-C oscillators which are not applicable to the class of switching oscillators.

Extensive experimental measurements were made on the spectral distribution of the noise in switching oscillators. These measurements, in conjunction with the nonlinear differential equation describing the statistics of the noise performance have enabled us to derive general expressions for noise in any switching oscillator with arbitrary noise inputs.

Our work on MOS crystal oscillators showed the need for MOS circuits capable of performing functions such as linear voltage-to-current conversion with wide dynamic range. Circuits such as this would allow realization of high-level functions such as analog multiplication, gain control, wide-band amplification and others. We investigated several methods of voltage-to-current conversion in MOS technology using systematic synthesis procedures. One of these realizations using cross-coupled active feedback in the NMOS devices yielded a wide-band (dc to 20 MHz) V-I converter with 0.1% distortion at 95% of full scale swing. Finally, our circuit investigations described above were complemented with process and device research which resulted in the fabrication of a new ion-implanted monolithic sub-surface reference diode. A well-controlled p-implant determines the breakdown voltage of 6.17 V with a very small standard deviation of 20 mV. Due to the sub-surface controlled avalanche process, long-term stability below measurement sensitivity of 1 mV was achieved. A complete monolothic circuit incorporating this diode and unique temperature compensating circuits yielded a reference with less than 8 ppm/°C temperature drift.

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D. Soo - Ph.D. Student (awarded M.S.)

J. Kukielka - Awarded Ph.D.

L. Jensen - Ph.D. Student

Ph.D. Dissertations

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